Master's thesis

The impact of visitor disturbance on breeding Eider (*Somateria mollissima*) populations at Dyrhólaey Nature Reserve: Implications for management

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Declaration

I hereby confirm that I am the sole author of this thesis and it is a product of my own academic research.

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Abstract

Managing the conflicts that occur between humans and wildlife is one of the primary concerns of reserve managers. As recreational use of the countryside increases, improving our understanding of disturbance impacts is vital in order to limit damage and to inform management of access on reserves. The aim of this study is to provide scientific advice to inform the management of visitors to Dyrhólaey Nature Reserve, Iceland.

This study first investigates how the reserve is used by humans and the study species, common eider. An experimental method is then used to establish Alert Distance and Flight Initiation Distance for incubating eiders. Historical data was also analysed to show long-term trends. These data were then used to estimate the potential impacts of disturbance under current management and advise future management.

Nest distribution across the reserve was varied with a concentration in less disturbed areas and around the reserve's one fresh water source; historical data implies that distribution has changed over time. Results indicated that eiders at this stage of breeding are not very sensitive to disturbance with a maximum alert distance of 5.2m and 45% of birds showing no response. Sensitivity was found to be higher in less disturbed areas.

The main conclusion of this paper is that, under current management, visitor disturbance is not likely to have a significant impact on incubating eiders on Dyrhólaey. Recommendations include the maintenance of buffer zones around key breeding areas and resources, encouragement of responsible access, and implementation of a monitoring program.

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1: Introduction

Managing the conflicts that occur between humans and wildlife is one of the primary concerns of land/resource managers. Human actions can have a significant impact on a species whether the action be deliberate extraction of individuals or merely shared use of habitat. The impact of extractive use of a species, for example the damage caused by a salmon fishery, is relatively easy to calculate; however less direct impacts are harder to measure or to quantify making the job of those attempting to balance use of the natural environment even harder. Wildlife disturbance is one such impact. This paper will investigate the impacts that recreational use of habitat can have on a species, in this case the common eider, to inform the management of visitors to this species' breeding site. The following sections give an overview of the issue followed by an introduction to the study area and species.

1.2: Recreational Access and Disturbance to Wildlife

Recreational use of the countryside, whether by local residents or tourists, is a common and global phenomenon. It is important to the human population for many reasons ranging from human health, to economic benefits gained from the tourist industry, to raising awareness of the environment (Burger, Gochfeld, & Niles, 1995). With increasing use in some areas, however, come concerns over the impact that these users are having on the increasingly vulnerable wildlife living in these areas (Gill, 2007). For example it is predicted that, as development and access pressures rise in coastal areas, interactions between recreational users and seabirds will increase thus increasing the potential for negative impacts on the birds (Velando & Munilla, 2011). Individually, or when combined with other detrimental pressures such as climate change, recreational access could potentially have significant impacts on wild species either breeding or otherwise utilising the area in question. Wildlife areas are often managed for both the resident wildlife and human users between which there are bound to be interactions and therefore conflicts; it is

the job of the manager to balance these different needs (DeLong, 2002). According to a research review undertaken by Scottish Natural Heritage the two primary concerns of managers when dealing with recreational access to an area are wildlife disturbance and damage to vegetation (Sidaway, 1994). Increasing our understanding of disturbance and the impacts of disturbance is vital in order to limit said impacts and to inform management of access to areas containing wildlife that could be at risk from disturbance (Bolduc & Guillemette, 2003). Scientific evidence is often required to guide management decisions relating to this issue (DeLong, 2002).

The magnitude of the impact of disturbance has been found to be highly species specific. Species which are dependent on an area for breeding or foraging are likely to be those at greatest risk from disturbance. Ground nesting birds, such as Eiders, are considered to be "particularly at risk from human disturbance". Incubating birds are often flushed from the nest by disturbance which has three main detrimental impacts: cooling of the eggs/chicks, increased risk of predation, and an energy cost to the adult bird (Finney, Pearce-Higgins, Yalden, & Langston, 2004).

The impact of disturbance to breeding bird populations is often hard to measure or quantify as many years of data, both before and after the disturbance begins/increases is needed to show population-level effects. Behavioural/physiological responses to disturbance, although they are only mechanisms for longer-term impacts, are often used to indicate likely impacts as they can be measured in one season. These can then be used to infer a possible effect at the population level, which is of primary importance to managers (Drewitt, 2007). Behavioural responses are also often used in preference to physiological responses as they are more easily quantifiable (Ellenberg, Mattern, Seddon, & Jorquera, 2006). The most commonly displayed responses of birds to disturbance are static responses such as increased vigilance or alarm calling and active responses such as flushing (Ruddock & Whitfield, 2007).

This study will investigate the effects of human disturbance on Dyrhólaey Nature Reserve in the south of Iceland where there is a conflict of use between visitors to the reserve and the conservation of the eider duck population breeding there.

1.3: Dyrhólaey Nature Reserve

Dyrhólaey is a rock outcrop in the floodplains of south Iceland. The reserve appears island-like and is connected to the land by sand/pebble beaches and a causeway which forms the vehicular access route to Dyrhólaey (Figure 1). Dyrhólaey is bordered on the south by the Atlantic Ocean which has shaped its cliffs, rock stacks and arches. To the north is a large brackish lake which is generally separated from the sea by the large sand banks on either side of Dyrhólaey but each spring a channel is dug through the sand which partially drains the lake; this is done to prevent flooding of the valuable farm land around the lake. Dyrhólaey can be divided easily into two distinct areas based on elevation: Lágey is the lower part with fairly even terrain before the 'island' rises steeply towards the lighthouse and highest sections of cliff including the arch or 'door' that gave Dyrhólaey its name (Umhverfisstofnun, 2012a). This higher part is called Háey. There are two main roads across Dyrhólaey one across Lágey to the car park at the east end of the island and one which zigzags up Háey ending at the lighthouse (Pers. Comm.).

Figure 1: An aerial view of Dyrhólaey, Iceland, showing the reserve boundary, footpaths, parking areas, and surrounding landscape including the various rock stacks (courtesy of Umhverfisstofnun).

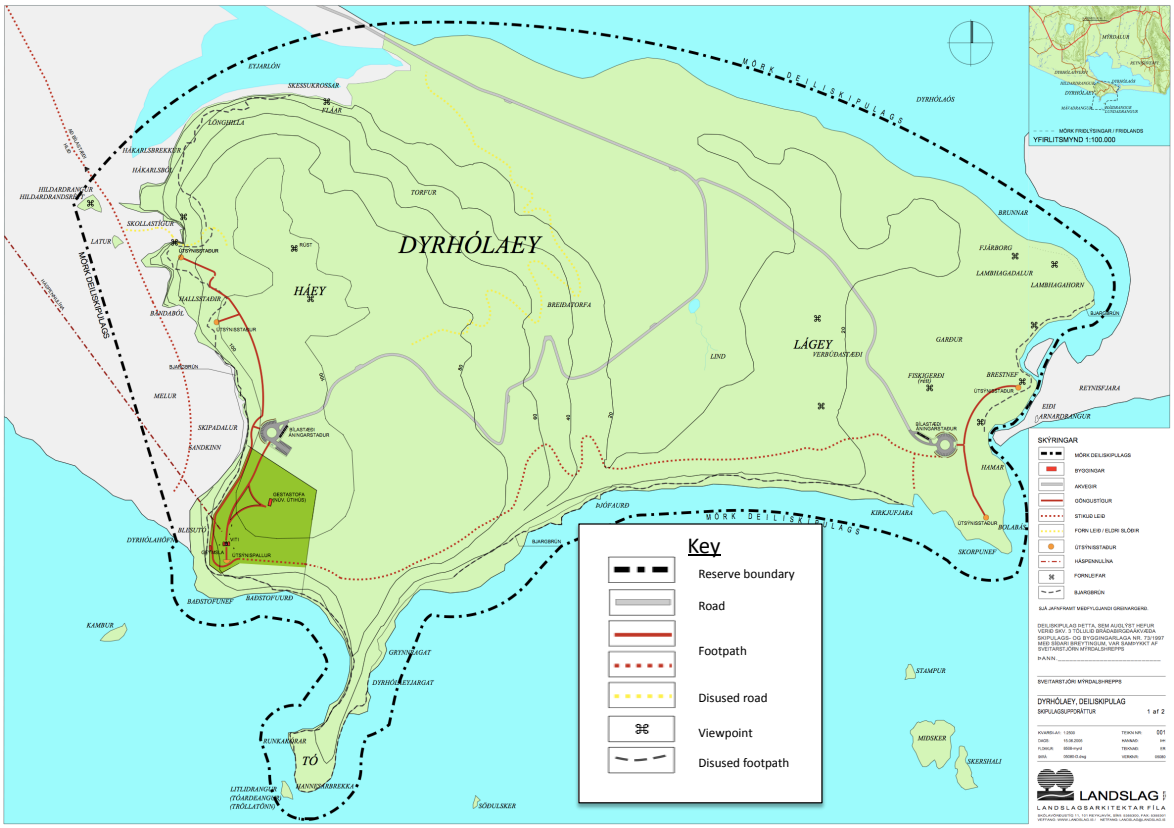

Figure 2: Map of Dyrhólaey, Iceland, showing reserve boundaries, vehicular and pedestrian access routes, and car parks (Landslag, 2005).

Figure 3: Photograph of Dyrhólaey, Iceland, showing the shape of the rock outcrop or 'island' from the North (inland) with Lágey to the left and Háey to the right (photograph by author).

Dyrhólaey was designated a Nature Reserve under Icelandic law in 1978 to protect its landscape and wildlife; of particular note is the rich birdlife found on the reserve (Umhverfisstofnun). Breeding species include common eider, atlantic puffin *Fratercula arctica*, common guillemot *Uria aalge*, razorbill *Alca torda*, arctic tern *Sterna paradisaea*, black-legged kittiwake *Rissa tridactyla*, northern fulmar *Fulmarus glacialis*, whimbrel *Numenius phaeopus*, and golden plover *Pluvialis apricaria*. Management of the reserve is undertaken by Umhverfisstofnun (The Environment Agency of Iceland) and, in recent years, a warden has been present on the reserve throughout the summer season. The

reserve is managed largely for the conservation of the species that live there and associated habitats, but is also open to the public and some traditional practices, such as down harvesting and grazing, are permitted (Sigurðarson, 2011). Actions which are prohibited on the reserve include: destruction/disturbance of flora/fauna, "construction/mechanical disturbance of the ground", and "off road driving" (Umhverfisstofnun).

Current uses of the reserve include tourism (largely relating to the Puffins and interesting rock formations), local recreational use such as walking or birdwatching, and eider down harvesting (Umhverfisstofnun, 2012a). Dyrhólaey is a popular destination for the large numbers of tourists that explore the south coast of Iceland each year and a large part of the management required on the reserve relates to this (Umhverfisstofnun, 2012a). The reserve offers vehicular access with two car parks, footpaths along the coast and to viewpoints, and visitor interpretation panels. The most intensively used paths are those leading to viewpoints close to the car parks (Sigurðarson, 2011).

Figure 4: Photograph showing Lágey taken from Háey, Dyrhólaey Nature Reserve, Iceland. Visible are the footpath across Lágey from the car park and the sand bar that connects Dyrhólaey to the mainland in the east, with the brackish lake behind it. To the right is the Atlantic Ocean (photograph by author).

In recent years there has been some conflict of use, largely between the down harvesters and the recreational users/tourist industry (Sigurðarson, 2011). Historically the reserve has been closed to visitors in June each year in order to protect the nesting eiders from disturbance. Umhverfisstofnun has the power to decide if, how, and when the reserve will be closed and this decision has, traditionally, been made each year (Þorsteinsdóttir, 2011). In addition to deciding the closing dates for the reserve, Umhverfisstofnun may also impose restrictions on access within the reserve or only open the reserve for part of the day (Umhverfisstofnun, 2012a). During the eider incubation period in 2012 the reserve was open from 09:00 till 18:00 each day and a warden was present during these hours. The vehicular access route to the lighthouse across Háey was also closed for the benefit if the nesting eiders. This route passes close to a concentration of nesting eiders and the only fresh water source on the island (pers. comm.).

In the past these restrictions/closures have been decided in the spring of each year. This has resulted in some concern from the local tourist industry, especially tour operators, as they have been unable to inform visitors whether or not they will be able to visit the reserve until the last minute. Umhverfisstofnun now aim to make a decision, in advance, on closure for an initial period of five+ years (Umhverfisstofnun, 2012b). This study aims to provide Umhverfisstofnun with recommendations regarding this closure with respect to the potential/likely impact of granting visitor access to the reserve on the breeding eider population.

1.4: The study species: Common Eiders (*Somateria mollissima*)

There are around 200 eiders nesting on Dyrhólaey each year and this number may have been much larger in the past. Down has traditionally been collected from the nests of these birds by nearby landowners; more details of this practice can be found in section 1.5 (Þorsteinsdóttir, 2011). Eiders are large seaducks commonly seen in Iceland. The female is brown with dark barring and is well camouflaged in vegetation. The male is largely black and white with a distinctive pale green nape and can be heard calling during the

breeding season with a sound which had been likened to a wolf whistle (Svensson, Mullarney, & Zetterström, 2009).

Figure 5: Photograph of male common eider duck (Somateria mollissima) on Dyrhólaey Nature Reserve, Iceland (photograph by author).

Figure 6: Photograph of a female eider (Somateria mollissima) on her nest on Dyrhólaey Nature Reserve, Iceland (photograph by author).

1.4.1: Ecology

Common eiders (*Somateria mollissima*) breed, winter and moult largely in circumpolar coastal waters. The main countries that support large populations of eiders are Iceland, Russia, Canada, and Norway (Merkel & Gilchrist, 2010). There are currently around 250,000 pairs breeding around Iceland's coasts (Bérdard, Nadeau, Giroux, & Savard, 2008). Eiders feed mainly on crustaceans and molluscs for which they dive to moderate depths (Svensson, Mullarney, & Zetterström, 2009).

Figure 7: Breeding and wintering range of common eiders (Somateria mollissima) in the circumpolar region (Merkel & Gilchrist, 2010)

Eiders are a long-lived species, with a high adult survival rate and only reach maturity after two to five years (Coulson, 1984). Each spring eiders return to the breeding grounds; this species generally returns to the same area each year, sometimes even using the same site (The Joint Working Group on the Management of the Common Eider , 2004). In Iceland females prospect for nest sites in late May/early June and begin to lay eggs from late May. One egg is laid each day until a full clutch of three to five eggs is reached and the incubation period is around four weeks (Bérdard *et al.* 2008). Clutch sizes can vary greatly between years often depending on the condition of the adult bird (Coulson, 1984). During

incubation female eiders leave the nest only to drink/eat and this only rarely. It has been reported that eiders generally leave the nest at night, when avian predators are less active (Bolduc & Guillemette, 2003). Eiders can utilise various habitat types for nesting from bare rock to long grass as can be seen by the photographs in Figures 6&8. Male eiders generally play little part in either incubation or chick rearing (The Joint Working Group on the Management of the Common Eider, 2004).

Figure 8: Photograph of eider (Somateria mollissima) eggs in a nest on Dyrhólaey Nature Reserve, Iceland (photograph by author).

Within a few days of hatching the females and ducklings leave the nest and make their way towards the chick-rearing grounds. It is vital at this stage that the ducklings have access to fresh water. Studies have shown that increased salinity in available water is correlated with increasing duckling mortality rates and decreasing duckling growth rates (DeVink, Gilchrist, & Diamond, 2005). Chick-rearing grounds are areas with suitable food sources, such as gastropods and gammarids, for the young eiders. These prey species are generally found in rocky substrates and macrophyte beds. Eider ducklings are very vulnerable to predation during the period between leaving the nest and fledging. Survival rates for this stage are estimated to be between 5-20% (Bérdard *et al.* 2008). One unusual feature of eiders as a species is that they practice créching when the ducklings are young. Females

will care for young in addition to their own, an unusual characteristic in the avian world, and non-breeding females will also assist with brood care (The Joint Working Group on the Management of the Common Eider, 2004).

The long life-span and high adult survival rate of eiders mean that it may take many years for evidence of population decrease to be measurable in breeding colonies. Colonies rely almost entirely on returning offspring from that colony for recruitment of breeding birds. Evidence for this is provided by studies showing that there is a strong link between years of high productivity/duckling survival and years of high recruitment. In hard years it has been observed that adult eiders may choose not to breed, a common trait in long lived birds as they can then reserve energy and ensure their survival for future years (Coulson, 1984). The low survival rates of ducklings means that recruitment to the population can be very low making the species vulnerable to environmental changes (Bérdard *et al.* 2008).

It should be noted that, due to their dependence on food resources in shallow marine environments, they can be a useful indicator species for the health of the oceans. This is particularly important for oceanic species as marine ecosystems are difficult to study so the use of indicator species is common (Merkel & Gilchrist, 2010).

1.4.2: Status

The most recent estimation of the global eider population is around 3,100,000-3,800,000 individuals (Birdlife International, 2012). The global population may be decreasing but is not thought to be doing so at a rate that would be of concern under the IUCN red list criteria. Under these criteria eiders are listed as being of 'Least Concern' due to the species' large range, population and low rate of population decline (Birdlife International, 2012). The large range of this species does, however, make it difficult to co-ordinate conservation efforts (The Joint Working Group on the Management of the Common Eider , 2004).

In 1997 the eider population in Iceland was listed as 'increasing', Iceland being the only nation listed as such (Circumpolar Seabird Working Group, 1997). The marine environment has undergone changes since 1997, changes that have been mirrored by

declines in other marine bird species populations (Frederiksen, Wanless, Harris, Rothery, & Wilson, 2004)(Joint Nature Conservation Committee, 2011). Declines in eider populations have been recorded in other circumpolar nations and have resulted in various eider conservation schemes. Exact causes of these declines are often unknown but human disturbance is listed as one of the main likely contributors (Merkel & Gilchrist, 2010).

One of the main contributing factors towards the relative success of eiders in Iceland compared to other nations is the eider down industry. The commercial value of this traditional industry in Iceland has resulted in various types of protection being afforded to the breeding eiders. Eiders are one of the few bird species that is protected by law in Iceland. It is prohibited to kill an eider or to utilise any caught accidently in fishing gear. It is also illegal to sell/gift either eider meat or eggs, although collection of eggs for personal use is permitted (Circumpolar Seabird Working Group, 1997). Due to the long history of eider down collection in Iceland "eider colonies, which are used for harvesting the down, can be declared closed to visitors" and "a no-fishing zone of 120 m offshore" can be established (Circumpolar Seabird Group, 2003).

1.4.3: Threats

Most species are threatened by the climate alterations currently occurring but there are many other more direct threats to eiders caused by humans. The main threats, globally, to common eiders listed by the IUCN are as follows (Birdlife International, 2012):

- Oil pollution
  A threat to all marine aquatic birds due to the damage and widespread mortality that oil spills can cause.
- Shellfish aquaculture industry
  This is due largely to competition for food resources and the measures taken by this industry to prevent eiders from feeding on their stock.
- Coastal development
  Development can result in loss of habitat and increased disturbance.
- Shore-based recreation and research

The main concern cited by the ICUN over this threat is that it can cause an increase in predation risk as eggs/ducklings become more vulnerable to predators when adult birds are disturbed.

- Tourism and shipping
  Result in disturbance from presence of humans, vehicles or noise..
- Entanglement in monofilament nets.
- Unsustainable hunting (sport and subsistence)
  This is not an issue in Iceland due to the hunting restrictions in place.
- An additional threat mentioned in Environment Canada's report on eider down collecting (Bérdard *et al.* 2008) is that of Avian Cholera *Pasteurella multocida* which has been known to wipe out whole colonies of eiders in Canada. Five thousand female eiders were lost to the disease in one outbreak in 1985 (The Joint Working Group on the Management of the Common Eider , 2004).

This study will focus on disturbance, in this case by recreational use of the coast as this is the threat most easily controlled by management of the reserve. Disturbance by humans is also listed as a threat in Conservation of Arctic Flora and Fauna's (CAFF) Eider Conservation Strategy and Action Plan (Circumpolar Seabird Working Group, 1997). A report compiled by Environment Canada states that disturbance during incubation increased the risk of egg/duckling predation, increased the risk of nest abandonment and can have physiological impacts on incubating eiders (Bérdard *et al.* 2008). The predation rate of eider ducklings by gulls has been reported to increase by up to 300% due to disturbance (Ahlund & Gotmark, 1989). The link between disturbance and the threat from native predators is highlighted in CAFF's conservation plan. In order to achieve its objectives the plan recommends that both the habitat utilised by eiders and the birds themselves be protected from disturbance, tourism, and development (Circumpolar Seabird Working Group, 1997). The main eider predators mentioned in the literature that are applicable to Iceland are gulls *Laridae*, arctic foxes *Vulpes lagopus*, common raven *Corvus coraxand,* american mink *Neovison vison* (non-native escapee) (Sveinsson)(Bolduc & Guillemette, 2003)(Circumpolar Seabird Working Group, 1997).

1.5: Down Harvesting

The common eider is the only duck which produces "commercially harvestable down" (The Joint Working Group on the Management of the Common Eider , 2004). Eider down has various desirable qualities particularly its thermal properties and softness. It is also light and breathable and is used to make luxury down clothing and comforters. It must be used to make luxury items simply because of the price of eider down; for example an eider down comforter can cost up to £7000 (Elysha charles). Each female eider sheds around 17g of the soft feathers from her underbelly during each breeding season; this down is used by the bird to line the nest and ensure that the eggs are kept warm, especially when the female has absented herself to drink or eat (Sveinsson).

Figure 9: Photograph of female eider (Somateria mollissima) on her down-filled nest with newly hatched ducklings, Dyrhólaey Nature Reserve, Iceland (photograph by author).

Down is collected by down harvesters from the eider nests at the end of the season after the bird has left the nest. Many collectors also collect all/a proportion of the down around the middle of the incubation period replacing it with straw. After collection the down is dried, often just using sunlight, and may be sorted into clean and dirty categories. Once dry the

down is cleaned using specialised equipment; this is generally owned by down-cleaning companies or co-operatives of down harvesters rather than individuals (Bérdard *et al.* 2008)(Smith, 2012).

Globally four to five tons of eider down is collected each year, the majority of this from Iceland (Bérdard *et al.* 2008). Around 3000kg of down is exported annually from Iceland to a variety of countries around the world (Circumpolar Seabird Group, 2003). It is estimated that there are around 350 down harvesters in Iceland, six main down processors, and seven wholesale exporters (Sveinsson). In Iceland eider down harvesting, processing, and export are all important components of the economy, perhaps particularly at a local scale. Down harvesting is rarely used as a sole income but rather as a supplementary one for landowners who have land suitable for eiders, often farmers (Smith, 2012). In addition to its economic value, down collection is also an important source of economic stability in a number of remote areas of Iceland, many of which have issues with human emigration. Down collection diversifies the industries in these small communities and has even been used as an additional tourist attraction (Granholm, 2011).

Down collection is a traditional practice in Iceland and evidence suggests that it may have been conducted since the Norse settlement of Iceland in the 9th century (Sveinsson). The relationship between the down harvesters and the eiders has been referred to as symbiotic due to the protection provided by the harvesters in return for the valuable down (Granholm, 2011). The protection provided by the harvesters varies depending on the individuals involved but often includes protection from human disturbance and/or the main predators such as arctic foxes. This interdependent relationship, in addition to the legal protection given to eiders in Iceland, is likely to have at least contributed to the more stable eider population in Iceland compared with those in other circumpolar nations (Doughty, 1979).

1.5: This study

1.5.1: Aims

The overarching aim of this study is to provide scientific advice to inform the management of visitors to Dyrhólaey Nature Reserve, focussing on the conservation of the breeding eider population. In particular, this study aims to provide advice relating to the closure of the reserve and/or access routes across the reserve in June each year for the protection of the breeding eiders. Detailed aims are listed below:

1. To assess the impact that visitors to Dyrhólaey could have on the incubating eiders on the reserve.
2. To provide advice on how any impacts found could be mitigated/avoided by altering visitor management.
3. To provide advice on further studies/monitoring that could be carried out regarding the management of access on the reserve.

1.5.2: Research Questions

In order to achieve the above aims this study asks the following questions:

1. How are the breeding common eiders (*Somateria mollissima)* distributed around Dyrhólaey Nature Reserve, Iceland in relation to visitor access routes and important natural resources: fresh water and food sources?

2. How do visitors to Dyrhólaey Nature Reserve, Iceland behave in terms of deviations from the marked access routes?

3. At what distance from the nest does human (vehicular or pedestrian) disturbance have a behavioural impact on incubating common eiders (*Somateria mollissima)*?

4. Questions 1, 2 and 3 are then combined to answer the following: Is it likely that, under current management regimes, the disturbance caused by visitors to Dyrhólaey Nature Reserve, Iceland has a significant impact on the breeding eider population?

5. Is disturbance-mediated predation an issue on the reserve? How high are the predation levels on Dyrhólaey Nature Reserve, Iceland and is predation higher in areas close to access routes?

6. Are there any long-term population trends observable in the common eiders (*Somateria mollissima)* nesting on Dyrhólaey Nature Reserve, Iceland? Has the distribution of nests on the reserve changed over time?

2: Theoretical Overview

The review of literature in the previous section clearly shows that conflict between recreational use and the conservation of wildlife is a common phenomenon. Evidence also suggests that the impact is highly species and location specific (Laurensen, Kahlert, & Frikke, 2005). Some information is available on impact of disturbance on eiders but again the impact appears to be very location specific (Keller, 1991) (Merkel & Gilchrist, 2010). No data is available on the impact of human disturbance on eiders on Dyrhólaey Nature Reserve and this study aims to fill this gap in order to inform management of the reserve. This is of particular importance because of large and probably increasing visitor numbers, concerns of both down harvesters and conservationists over potential impacts, and a decision by the managers of the reserve to create a long-term management plan regarding the closure of the reserve during eider breeding season. To achieve this goal, this study will use various methods to investigate the likelihood of contact between visitors and nesting eiders and the response of eiders to human disturbance. Both observational and experimental methods will be utilised, further description of which is given below and in the methods section.

This study potentially also has wider applications beyond the specific reserve studied. Although largely focused on this individual case the data collected for this study and the recommendations drawn from it may be applicable to other areas of Iceland where eider colonies and recreational use coincide. The methods that will be used to assess the issue could be replicated or even applied to other species for either a commercial or purely conservation aim. The methods used are also designed to be applicable with limited time and resources available to the researcher and as such may be widely applicable.

The following sections give a further review of the literature relating to the study of disturbance, the rational for the selection of the methods used in this study, a summary of these, and an explanation of the limitations of the methods and results of this study.

2.1: Methods: literature review

Many studies have investigated the potential of human disturbance, particularly that caused by recreational access, to negatively impact breeding bird populations (Ruddock & Whitfield, 2007). A variety of methods have been used in this study, the selection of which has often depended largely on the baseline data, time and resources available, and the species being studied. There are also various ways to answer the question 'is disturbance having a negative impact on this species?' Studies on the impact of disturbance have been conduced at everything from the population to the individual level. When producing scientific evidence to guide management of a nature conservation area the methods, and therefore type of results selected, often depends on how the data is going to be used by the managers of the site (Gill, 2007).

To investigate if disturbance is impacting a population under current management, ideally a long-term data set would be used to compare to contemporary data demonstrating whether the population or productivity has changed and whether this correlates with any change in human activity or management of the site in question. This would then show the long-term population level impact of disturbance. However this requires a strong set of baseline data preferably spanning many years and corresponding data on the level and type of disturbance (Drewitt, 2007) (Gill, 2007).

Another method which can be used to infer a likely impact due to disturbance is that of alert distance (AD) or flight initiation distance (FID). Alert distance is a static response and is defined as "the distance between the disturbance source and the animal at the point where the animal changes its behaviour in response to the approaching disturbance source". The flight initiation distance is an active response and is defined as "the point at which the animal flushes or otherwise moves away from the approaching disturbance source" (Ruddock & Whitfield, 2007). The most common method used to establish ADs or FIDs is for a single human to approach an individual or group of the study species and record the distances at which responses are elicited (Laurensen *et al.* 2005) (Bregnballe, Aaen, & Fox, 2009) (Bentrup, 2008) (Ruddock & Whitfield, 2007). Scottish Natural Heritage used this method to establish the distance at which human presence causes disturbance to 26 priority species to aid management of designated sites in Scotland

(Ruddock & Whitfield, 2007). It has been suggested that the use of ADs is preferable than that of FIDs due to the increased sensitivity of this method. However for some species ADs can be hard or impossible to measure so FIDs are used (Fernández-Juricic, Jimenez, & Lucas, 2001)(Fernandez-Juricic, Venier, Renison, & Blumstein, 2005). An example of how this method has been used to assess disturbance impacts is the Solent disturbance and mitigation project. This project has undertaken a large scale study which combines ADs with other methods to estimate disturbance in the Solent area with the aim of producing a management plan to mitigate any impacts found. The study looks at the how the area is used by both bird species, including locating resources with importance to the species, and humans; it then compares this to the disturbance distances to calculate the likelihood of encounters and therefore disturbance impacts (Solent Forum, 2013).

This method is also used in the creation of buffer zones – a commonly used management tool whereby areas around critical wildlife sites are created in which human use is either prevented or restricted so as not to disturb the wildlife (Bentrup, 2008) (Ruddock & Whitfield, 2007). Critical wildlife sites could refer to both breeding habitat and foraging areas or water sources. The creation of buffer zones using ADs or FIDs can be an excellent way to allow humans to use these protected areas and even to view the species living there without harming said species (Fernandez-Juricic *et al.* 2001). Again, the use of ADs over FIDs is recommended as being more likely to prevent all forms of disturbance especially as some species will only flush as a last resort (Fernandez-Juricic *et al.* 2005). It is also recommended that measures of ADs/FIDs taken from the species and site in question should be used as these measures can be both site and species specific (Blumstein, Fernandez-Juricic, Zollner, & Garity, 2005). A report on the creation of protective buffers suggests the addition of 130-170 feet to the FID to ensure that visitors do not cause disturbance to sensitive species (Bentrup, 2008).

One limitation of this method is that ADs and FIDs can vary depending on various conditions, so generalisation is difficult. Different response distances have been recorded, within one species, at different times during a breeding season, in different habitats, when birds are in different conditions and at different population densities (Laurensen *et al.* 2005). In their study Scottish Natural Heritage found that distances were often greater during chick rearing than during incubation. This applies to, for example, common scoters

(*Melanitta nigra*) (Ruddock & Whitfield, 2007). Other studies have found that eiders are also generally more sensitive to disturbance during chick rearing (Keller, 1991)(Donehower & Bird, 2008).

2.2: Methods: selection and limitations

The selection of methods used in this study was strongly dependant on the availability (or lack thereof) of baseline data, the time available for data collection and the requirement to provide information to guide management of access. This resulted in the selection of AD and FID as the most appropriate method both to assess the likely impact of current management and to provide data to inform management of access.

Neither the current population nor current productivity could be compared with that of previous years to establish the effectiveness of current management due to the lack of baseline data available. There was also little data available on the number of visitors using the reserve each year so no correlation with disturbance levels could have been made even had past data been available (Þorsteinsdóttir, 2011). The time available for the collection of field data was also a strong limiting factor as only part of one eider breeding season was available. This again prevented the comparison of data between years. It also prevented a full productivity study for the 2012 breeding population being undertaken or data on eider activity after the incubation period being collected, for example duckling survival rates. These limitations resulted in a decision that assessing population or productivity impacts of disturbance on eiders on Dyrhólaey was not possible.

This study, instead, uses data collected from the responses of individual birds to human disturbance to infer potential impacts on the breeding eider population on Dyrhólaey. There are various methods for assessing the response of breeding birds to human disturbance. Both stress and behavioural responses are used to assess the likely impact of disturbance and responses that can be measured include increased heart rate, altered hormone levels, flight, decreased incubation time, and alternative foraging behaviour (Gill, 2007). Of these flight (and the other behavioural responses shown by eiders prior to flight) were selected as the most practical and most effective measure for this study due to the

resources available; the other responses all require specialised equipment. These responses are clearly visible and easily quantifiable making them highly suitable for a field-based study. Both ADs and FIDs are used; AD because this gives the most sensitive measure and FID because the cost of this response it potentially much higher than that of AD due to increased predation risk (Keller, 1991). Previous research has used the flushing response of birds, including eiders, to infer a disturbance-mediated impact; one study on eiders demonstrated a clear link between the flushing response and the productivity (Bolduc & Guillemette, 2003). Like the Solent disturbance and mitigation project this study uses a combination of ADs/FIDs and other methods to estimate the impact of disturbance on eiders under the current visitor management regime (Solent Forum, 2013).

The ADs and FIDs measured will also be used to advise Umhverfisstofnun in the creation of buffer zones around the nesting eiders, if necessary. In the past closure of the reserve effectively created a large buffer zone around all nesting birds and under current management the closure of the road to Háey increases the buffer zone around the eiders nesting in that area. This study uses the above metrics and the locations of the eider nests in relation to access routes to establish the most important areas for the creation of buffer zones and therefore which access routes should be closed or open. This method has been used in the creation and management of visitor access to various other nature reserves and wilderness areas (Bentrup, 2008) (Ruddock & Whitfield, 2007).

This method does have various limitations. Using behavioural responses to estimate the magnitude of an impact is not ideal as they show only a reaction rather than an actual impact. Other studies have used behavioural responses as an indicator for longer-term impacts such as a decrease in population or productivity (Solent Forum, 2013)(Velando & Munilla, 2011). Most behavioural responses have some kind of cost to the animal whether an energy cost of a stress response or a reproductive cost. As stated earlier there can also be a lot of variation in AD and FID under different conditions. Due to limited time birds could only be tested during one part of the breeding season (incubation) and it is likely that they may be more sensitive to disturbance during earlier or later stages, particularly during chick rearing (Keller, 1991)(Donehower & Bird, 2008). This stage was selected as the most appropriate to carry out the experiment because incubation is the time at which the eiders most intensively use the parts of the reserve which contain the majority of access

routes (Pers. Comm.). After hatching the birds do not remain long on the reserve but leave for areas nearby which have a source of food for the ducklings. Responses can also vary depending on the type or magnitude of disturbance; in the case of recreational use responses can vary depending on visitor group size or presence of dogs (Beale & Monaghan, 2004) (Ruddock & Whitfield, 2007). Dogs are not permitted on Dyrhólaey so this was not included in the method. Unfortunately the resources were not available to test birds' reactions to larger groups of pedestrians. An observational method to assess this was attempted but was found to be impractical.

Experimental methods like the one used in this study involving introducing human presence to a subject have also been used to study the impact of disturbance on productivity within one season using a nearby group of eiders as a control. To do this the colony was visited at different times during the season and at the end the productivity of the 'disturbed' colony was compared with that of the undisturbed control colony (Bolduc & Guillemette, 2003). This method was rejected for this study for various reasons. Firstly time constraints made measuring final productivity difficult; secondly the deliberate and repeated disturbance of nesting birds was deemed damaging to the conservation aims of the reserve; thirdly with a colony this small the sample sizes available for such an experiment would have been too small to be statistically valid especially since, in high concentration areas, all birds would be disturbed.

2.3: Methods: summary

This study uses a variety of methods to answer the research questions listed above. Methods used are largely observational with one experimental study and include an investigation into any historical records which could provide valuable insight into past population levels and nest distributions. The field data was collected on the reserve in June 2012 during the eider breeding season. Historical records were also located, collated and digitised during this period. The following paragraphs summarise the methods to be used and how they will achieve the aims above.

Firstly a visit to the study site was used to locate breeding birds, important resources such as fresh water, and the main access routes used by visitors to the reserve. This could then be used to assess the likelihood of contact between visitors and nesting eiders and establish the minimum distance between a nest site and an access route. A simple observational method was also used to investigate whether or not visitors leave the marked access routes and are therefore likely to disturb eiders nesting at a greater distance.

In order to establish the distance at which nesting eiders were likely to be impacted by human disturbance an experimental method in which the two metrics described above (AD and FID) was used. The method used was the approach of a single pedestrian towards an incubating eider and the distance(s) at which the bird responds was recorded. Combined with the location of nests with respect to access routes this was used to infer a potential impact of current management on nesting eiders. As described above this data was also used to provide recommendations on the creation of buffer zones.

Unfortunately this sort of method cannot be used to assess the impact of vehicular disturbance or disturbance by larger groups of visitors. A simple observational method must be used instead relying on suitable nests (near a road/path and visible from a suitable distance) being available for use. The impact of non-visible disturbance such as noise was not investigated in this study.

Due to the strong evidence available indicating that disturbance-mediated predation is of concern for ground-nesting birds including eiders the number of predated (and unpredated) nests found was also recorded. This both establishes a baseline on which to compare later years' data and may indicate the level of damage that disturbance is currently doing. The method selected for this was the standard method used for nest predation studies on eiders: recording the number of (fully used) nests found to contain no empty eggshells. This is commonly found in eider colonies and is considered a strong indication that the nest has been predated, all eggs removed (Bolduc & Guillemette, 2003). The magnitude of predation is important as this is one of the primary threats to eider productivity and has been shown to be strongly linked to human disturbance (Bolduc & Guillemette, 2003) (The Joint Working Group on the Management of the Common Eider , 2004) (Donehower & Bird, 2008).

Although no published data on the eider population or productivity on Dyrhólaey there are other sources of data, for example the records kept by the down harvesters, that could indicate past trends. These were investigated and collated during the study courtesy of the current down harvester Eva Dögg Þorsteinsdóttir. Many ecological studies lack baseline data and researchers often find that records kept by local users are a valuable resource. The records kept by puffin hunters in Iceland is an excellent example and an eider down harvester in Canada has kept records of eider populations since 1982 which are now being utilised by conservationists (Nova Scotia Government, 2009).

3: Methods

3.1: Distribution of eider nests.

Aim/background

The aim of this method was to establish the distribution of eider nests on Dyrhólaey in relation to sources of human disturbance and important resources such as fresh water. This was then used to estimate the extent to which nesting eiders were likely to encounter human visitors under the current management. This data was also used to establish a comparison between groups of birds experiencing different levels of disturbance by dividing the reserve into areas where birds were likely or unlikely to encounter human visitors (referred to as 'disturbed' and undisturbed' areas respectively).

The data collected from this method was also combined with the experimental data to estimate the impact of disturbance on the reserve and to provide recommendations regarding the creation of buffer zones.

Method

At the beginning of the field season in June 2012 the estimated positions of the majority of eider nests on the reserve were recorded on a map. This procedure was undertaken again later in the season in collaboration with the Reserve Warden and the down harvester using a GPS to record the exact position of all nests. For any nests within 50m of a footpath or vehicle track the distance between the nest and the path/track was measured using a tape measure. Nest densities will be used to infer where the main nesting areas are.

Human use of the reserve (access routes, car parks, viewpoints) was also opportunistically recorded and anecdotal notes were made on the extent to which areas were used by

visitors. Any important resource for the eiders (any resource observed to be regularly used by eiders) was also mapped, for example the single fresh water source on Lágey. This was done during other fieldwork and any information that could be of use was noted.

For analysis of the results from the experimental part of the study (see section 2.3) nesting areas were divided into two categories: 'disturbed' and 'undisturbed'. These categories are based on the nest's location on the reserve and reflect the likelihood of an incubating bird encountering human disturbance (see map below). Disturbed nests are those within sight of the pedestrian and/or vehicular access routes across the reserve. Undisturbed nests are those around the north and east of the reserve at the edge of the brackish lake; due to the nature of the landscape these nests are not visible from the visitor from the road or paths and there are no access routes to them. The only human disturbance, either presence of a human or noise disturbance, that they are likely to encounter is that of the occasional visits of the down harvester.

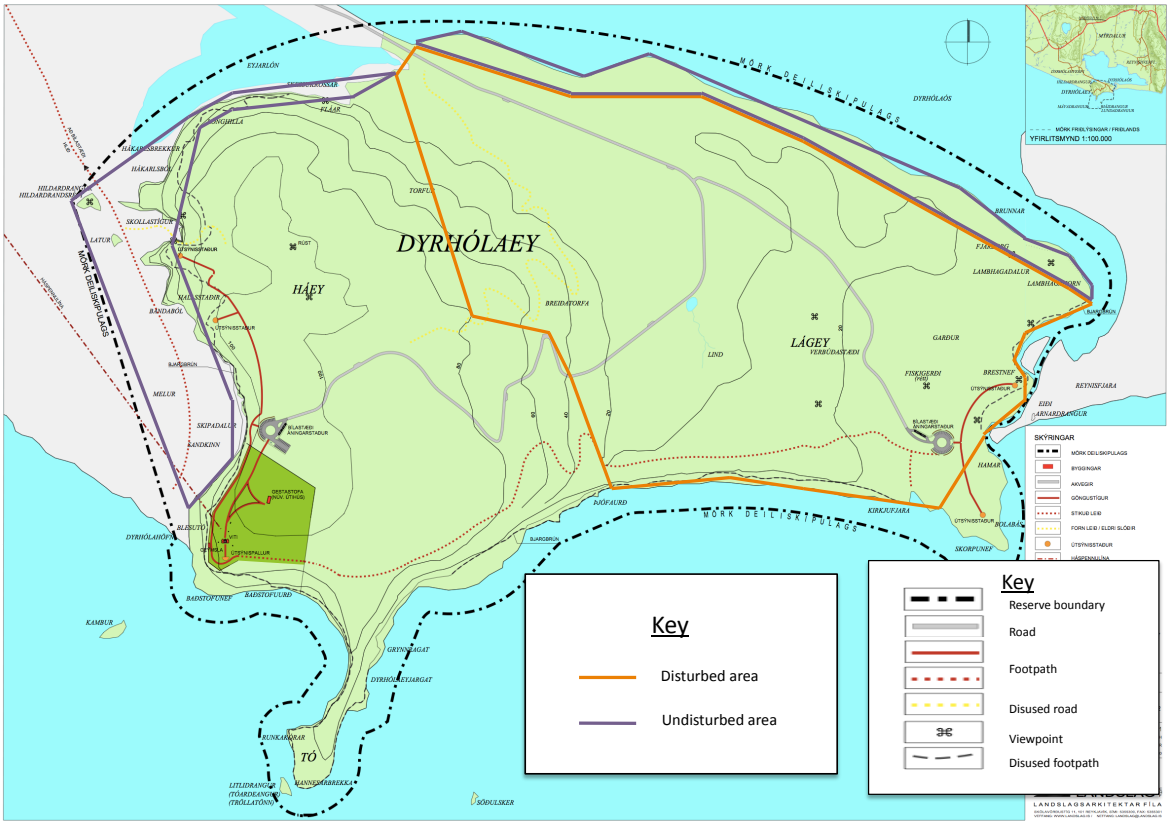

Figure 10: Map of Dyrhólaey Nature Reserve, Iceland, showing the main eider breeding areas divided into locations likely to encounter visitors (disturbed) and those unlikely to encounter visitors (undisturbed) (adapted from: (Landslag, 2005)).

Figure 11: A large concentration of eiders on the north side of Dyrhólaey Nature Reserve, Iceland. The brackish lake and narrow shoreline are largely undisturbed due to the lack of access routes along this edge of the reserve and the small cliff around the edge of the lake which hides this area from view (Photograph by author).

3.2: Visitor observations

Aim/background

The aim of this method was to establish the frequency and behaviour of visitors to the reserve. This observational study and casual observations made during the season were used as an indicator for how often visitors deviated from the marked access routes. Limited time was available to undertake these surveys so these results give only an indication of the behaviour of visitors. The small sample sizes make any further analysis of this data inappropriate.

Method

Vantage point observations were made on the reserve at different times of day/in different weather conditions over the period of a week in June 2012 during the main eider incubation period. Observations were made for a total of 5.25 hours and the researcher was able to view most of the access routes across Lágey where the eiders nest (see Figure 4 which shows the areas visible from the viewpoint selected). All vehicles present at the start of the survey and those entering the reserve during the survey were recorded. An average of the number of vehicles per hour was then calculated. All visitors walking along the main path from the car park to the lighthouse were recorded and an average of the number of visitors per hour was calculated. Any transgressions made by visitors were recorded along with details of the number of visitors in the party, their location, their activity, and the length of time spent away from the path.

3.3: Behavioural response of breeding eiders to human disturbance.

Aim/background

This method, combined with the data from the methods described above, aims to estimate the impact of disturbance on the reserve under the current visitor access management regime and to provide recommendations regarding the creation of buffer zones. The initial aim of this method is to establish the AD and FID of female eiders on Dyrhólaey during the incubation period. Incubation is the stage at which the birds most intensively use the areas of the reserve which contain visitor access routes. A full explanation of the reasons for the selection of this method is given in section 1.6.

The response of birds to disturbance can vary under different conditions. It was not possible to test the eiders under all conditions during this study due largely to time limitations. Eiders nesting in all areas of the reserve were tested to control for differences

in acclimatisation to disturbance and habitat type. It was not possible to test the birds' responses to larger groups or at other times during the breeding season, for example prospecting/early incubation or chick rearing. It is likely that ADs and FIDs would be different under these conditions. The eiders may also react differently in different years as the weather conditions or their state of health alters.

Method

Fieldwork was carried out in June 2012 during mid/late incubation. Nests in all areas of the reserve were selected, their location plotted on a map, and their proximity to footpaths/vehicular access routes recorded. A total of 49 nests were used; 28 in the 'undisturbed' areas and 21 in the 'disturbed' areas. Incubating birds were approached by a single pedestrian and their response(s) and the distance(s) at which they responded to the presence of the researcher were recorded. The behaviours observed are given below, both AD and FID metrics were measured. Individual birds were only approached once during the study to avoid any invalidation of the results by birds becoming accustomed to disturbance and so altering their responses.

Behaviours:

1) Bird sits upright and looks around – "**sitting**". This is one of the most typical alert responses observed in birds sometimes referred to as "increased vigilance". The other most common response is alarm calling, a response which incubating eiders do not display (Fernandez-Juricic & Schroeder, 2003)(Ruddock & Whitfield, 2007).
2) Heavy/deep breathing – "**Heavy Breathing**". This is another static response that has been recorded in eiders.
3) Bird leaves nest – "**flushed**". This gives the FID.

3.4: Vehicular disturbance observations

Aim/background

This method aims to investigate the response of incubating eiders to vehicular disturbance. As with the previous methods behavioural responses were used to estimate the significance of the disturbance impact. It was not possible to drive a vehicle towards incubating birds so observations were made of nests near the access road across the reserve using visiting vehicles as the source of disturbance. This means that ADs and FIDs for vehicles could not be measured. Unfortunately only one nest within fifty metres of the road was still active.

Method

The only suitable eider nest within 50m of the main access road across the reserve was observed during the late incubation period on two occasions in June 2012 at different times of day. Vehicular traffic, both numbers and types of vehicles, and any response that the bird made to passing vehicles were recorded. The researcher was not visible to the bird during these observations to ensure that the researcher's presence did not compromise the data.

Behaviours:

1) "sitting"
2) "heavy breathing"
3) "flushed"

3.5: Nest predation

Aim/background

This method aims to establish the rate of breeding failure due to predation at the incubation stage comparing failure rates in disturbed and undisturbed areas and establishing a baseline with which to compare future years' data. This is important as predation is one of the main threats to nesting eiders and has been shown to be strongly mediated by disturbance (Bolduc & Guillemette, 2003) (The Joint Working Group on the Management of the Common Eider , 2004) (Donehower & Bird, 2008). The method of ascertaining that a nest was predated was that used in previous studies on eiders (Bolduc & Guillemette, 2003).

Method

Any nests found to be predated, as well as their location, were recorded by both the researcher and the down harvester Eva Dögg Þorsteinsdóttir. Predation was assumed for any nest that was not found to contain egg shells after the adult bird had left (Bolduc & Guillemette, 2003). A percentage of birds that successfully hatched chicks was then calculated for the 'disturbed' and 'undisturbed' areas. Potential predators observed on the reserve (both resident and visitors) were also recorded.

3.6: Historical data

The Dyrhólaey down harvesters have kept records of both numbers of eider nests and their locations on the reserve for many years and the researcher was kindly given access to this data by Eva Dögg Þorsteinsdóttir. Data was obtained for the years 1992-1996, 1998-1999, 2006-2008 and 2011-2012. In these records the reserve was divided into 24 areas and the

number of nests from which down was collected in each area each year was recorded. See Figure 12 for a map showing the different areas. The data was taken directly from the written records and the areas were combined to correspond to the disturbed and undisturbed areas in figure 10 for data analysis.

Figure 12: Map of areas used by down harvesters to record eider nest data on Dyrhólaey Nature Reserve, Iceland. Areas 1-3 and 20-24 are classed as 'undisturbed' for the purposes of this study (courtesy of Eva Dögg Þorsteinsdóttir).

This data may have some limitations as it has been collected by different down harvesters over the years and without a specified method, but these are the only historical records

available. The total number of nests may not be representative of the whole reserve as not all areas were searched each year. The effort input may also have varied between years.

Data on the weight of down collected each year was also obtained from both the down harvesters and the down-cleaning company. If data was available from both sources an average of the two figures was used. The number of nests was calculated as 23 multiplied by the number of kilograms of uncleaned down. This method was taken from (Bédard, Nadeau, Giroux, & Savard, 2008) which states that 23 eider nests produce an average of one kilogram of down.

3.7: Ethical considerations

Although some disturbance of the birds was necessary to complete this study this was minimised as much as possible by only using nests/areas once during the study and carrying out the work as quickly as possible. Any time that a bird was flushed from the nest the researcher covered the eggs in the down (as the bird does when leaving the nest to drink) in order to maintain the incubation temperature and prevent predation. This is standard procedure for working with eiders (Bolduc & Guillemette, 2003). As mentioned earlier some methods were rejected on the basis of ethical considerations as they may have caused unnecessary harm to the breeding eiders.

3.8: Permits required

The project and the work proposed was discussed with the managers of the reserve and official permission was obtained from Umhverfisstofnun.

4:Results

4.1: Distribution of eider nests.

A total of 234 eider nests were located in the 2012 breeding season on Dyrhólaey (see Figure 13). Nests were found across most of Lágey with a large concentration along the northern shoreline. Very few nests were found on Háey which is concurrent with previous years.

Figure 13: Map of GPS locations of eider duck nests on Dyrhólaey Nature Reserve, Iceland, in June 2012. Road shown on map is the road to Háey, Lágey road is not depicted (Umhverfisstofnun, 2012b).

Five nests were within 50 meters of either a pedestrian or a vehicular access route. The smallest distance between a nest and an access route was five meters; this nest was close to the footpath leading from the car park on Lágey to the lighthouse. There were also four nests within 50 meters of the closed (Háey) road.

As stated in the methods section the reserve was divided into disturbed and undisturbed areas based on visitor access routes. Greater than three times more nests were found in the undisturbed areas compared with the disturbed areas (see table 1).

Table 1: Number of eider nests found in the disturbed and undisturbed areas on Dyrhólaey Nature Reserve, Iceland, in 2012.

Area	Number of nests
Disturbed	56
Undisturbed	178

4.2: Visitor observations

Visitors generally kept to the marked paths with only one transgression recorded during the observations. In this instance two visitors left the path and approached the cliff edge in order to photograph the non-breeding eiders there. The birds remained for a minute but then moved away. Another two visitors briefly followed the example set by the first couple but then moved on. This occurred very close to the section of cliff that had collapsed injuring a visitor a few weeks earlier.

Another transgression was recorded opportunistically by the researcher. In this instance two visitors had left the path to find somewhere to sit and have lunch. They were around ten meters from an incubating eider.

Vehicles remained on the paved roads/car park at all times but were observed to stop at the end of the closed road on several occasions. Drivers/passengers then left the vehicle to look/take photographs and, on one occasion, to walk towards the coast out-with the marked access routes.

Visitor numbers varied throughout the day and with the weather conditions. The table below gives the average numbers per hour during the observation periods. Vehicles were counted as they entered the reserve; pedestrians refers to those walking from the car park

on the path towards the lighthouse. Many visitors only use the short path and viewing points very close to the Lágey car park.

Table 2: The average number of visitors (pedestrians, cars and buses) to Dyrhólaey Nature Reserve per hour recorded during the visitor observation periods in June 2012

Pedestrians/hour	5.71
Cars/hour	15.76
Buses/hour	3.06

4.3: Behavioural response of breeding eiders to human disturbance

The map below shows the nests used in the experiment and shows which were considered to be in 'disturbed' and 'undisturbed' areas.

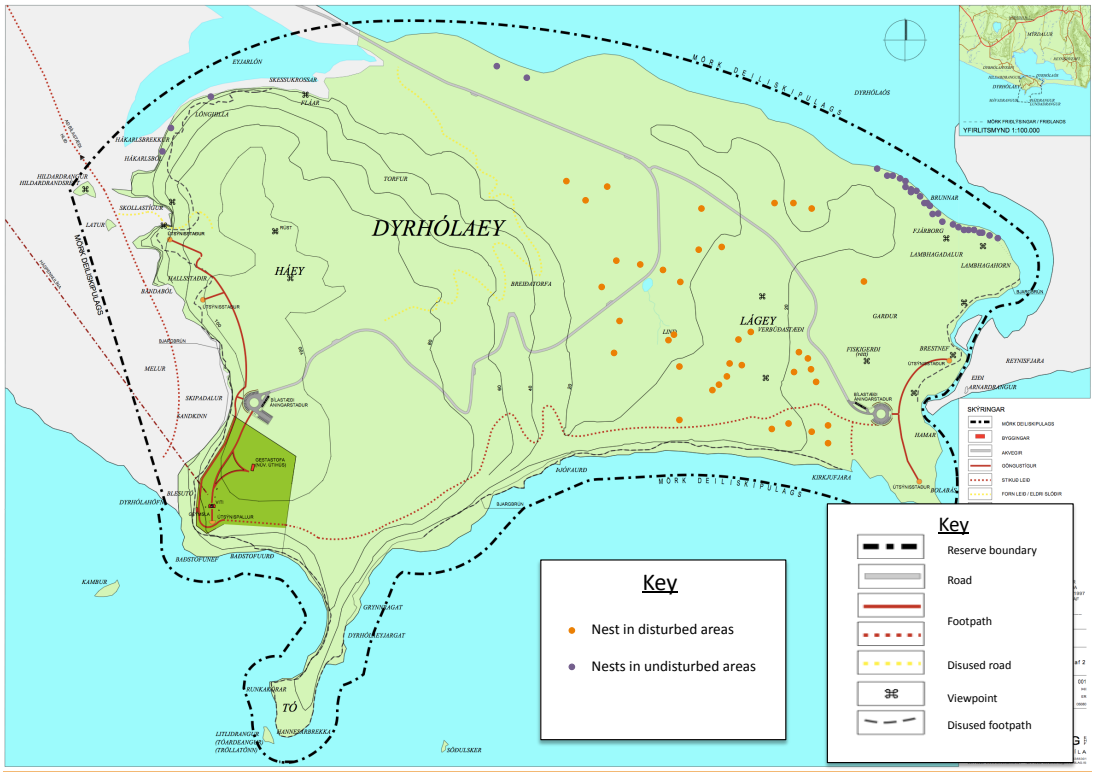

Figure 14: Map showing eider nest locations on Dyrhólaey Nature Reserve, Iceland, in 2012 for the nests used in the disturbance experiment (adapted from: Landslag, 2005).

4.3.1: Whole study population

Incubating eiders showed all response types (no response, heavy breathing, sitting and flushing) to the presence of the researcher ("human disturbance"). Responses differed between nests and areas both in terms of response type and the distance at which birds responded.

The largest distance that a response was elicited at was 5.2 meters so this can be taken as the maximum Alert Distance (AD), since the response recorded was 'flushed' this is also the maximum FID for this study. Minimum and maximum distances at which responses were observed as well as the average (mean) distance at which birds responded are given in the table below.

Table 3: The minimum, maximum and mean alert distances recorded for eiders on Dyrhólaey Nature Reserve, Iceland.

	Alert distance (m)
Minimum	0
Maximum	5.2
Mean	1.24

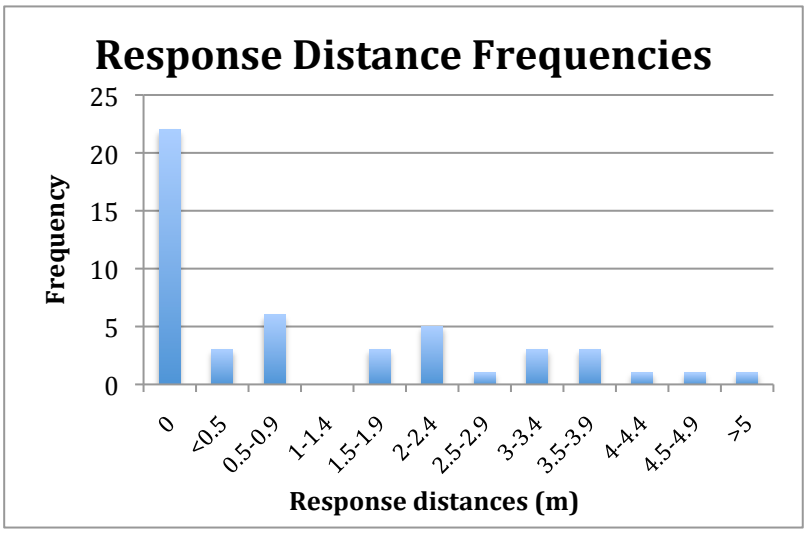

Figure 15: The number of incubating eiders which responded to human disturbance at each distance on Dyrhólaey Nature Reserve, Iceland. Distances have been divided into 0.5m categories for visualisation.

Just over half (51%) the incubating birds were flushed by the human disturbance while most other birds (45%) showed no response. A small number of birds showed static responses (heavy breathing and sitting) but only 4% showed only these responses and did not, later, leave the nest. The sitting response was always followed by the bird leaving the nest as the researcher continued their approach. The maximum distance at which the bird was flushed (the most severe of the responses) was 5.2m.

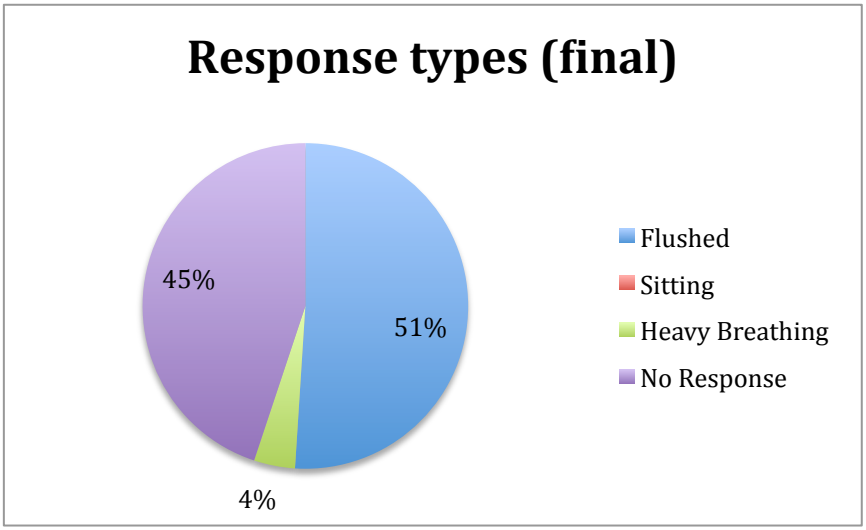

Figure 16: The final responses of incubating eiders to human disturbance on Dyrhólaey Nature Reserve, Iceland.

4.3.2: Disturbed versus Undisturbed areas

There were strong differences between the responses observed in the undisturbed areas compared with those in the disturbed areas.

The percentage of birds tested that showed a response to human presence was higher in the undisturbed areas; 79% in the undisturbed area responded compared to 24% in the disturbed area. Alert distances were significantly higher ($p<0.005$) in the undisturbed areas with both the maximum AD and the mean AD found to be higher (see table 4).

Table 4: The maximum and mean alert distances for incubating eiders in disturbed and undisturbed areas on Dyrhólaey Nature Reserve, Iceland.

Area	Maximum Alert Distance (m)	Mean Alert Distance (m)
Disturbed	3.9	0.46
Undisturbed	5.2	1.83

The type of response displayed by birds in disturbed and undisturbed areas was also clearly different. The number of incubating birds that demonstrated the 'flushing' response was much higher in the undisturbed area compared to the disturbed area (see Figure 17). The number that showed no response was correspondingly higher in the disturbed area compared to the undisturbed area.

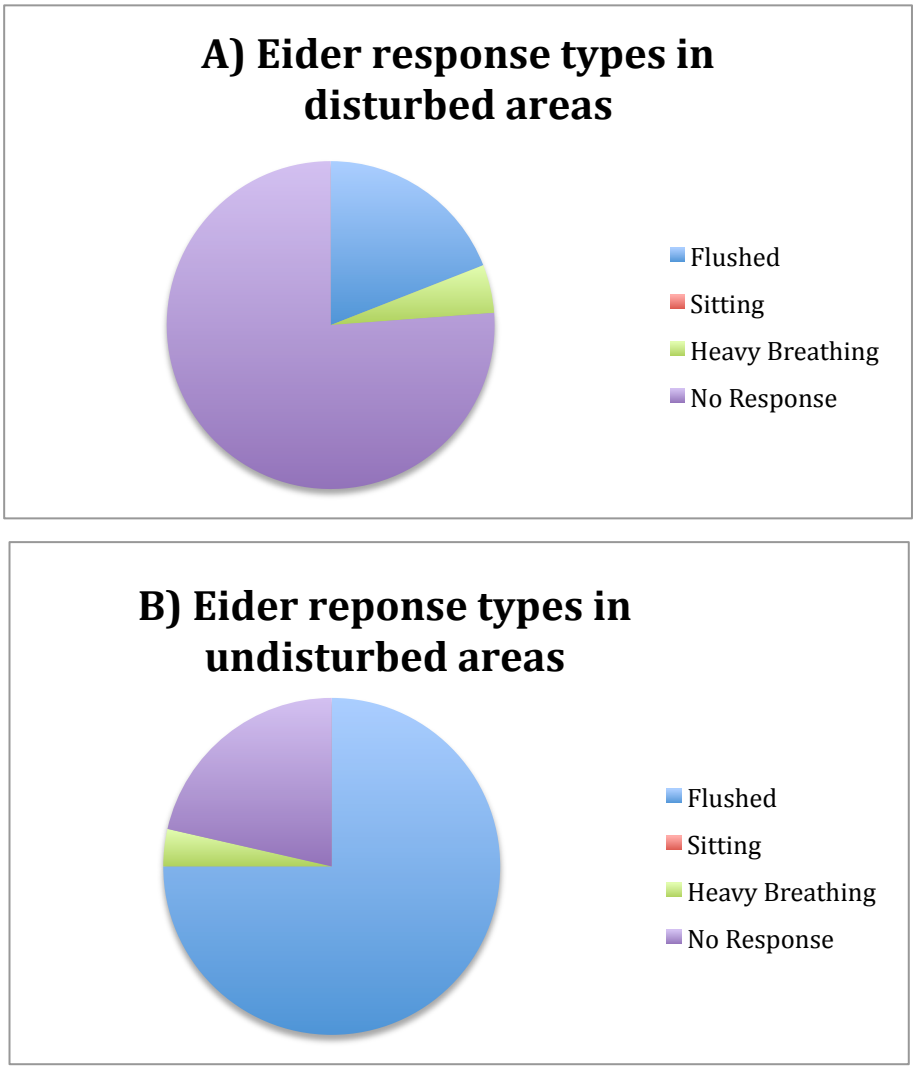

Figure 17: The (final) response types of incubating eiders to human disturbance in a) disturbed and b) undisturbed areas on Dyrhólaey Nature Reserve, Iceland.

4.4: Vehicular disturbance observations

The incubating female observed showed no response to any of the vehicles which passed the observed nest. Vehicles included cars and busses as well as convoys of up to four vehicles passing at once. The bird responded briefly (response type: sitting) to two pedestrians walking along the road. The average number of vehicles passing the nest per hour was 19.2.

4.5: Nest predation

The number of nests found to have been predated in 2012 was low with only seven of the 234 failing to hatch chicks. The number of predated nests was significantly higher ($p<0.05$) in the disturbed areas compared to that in the undisturbed areas. All the nests within 50 meters of an access route, however, successfully hatched chicks. The potential predators that were observed on the reserve were arctic skuas *Stercorarius parasiticus*, great skuas *Stercorarius skua*, and gulls *Laridae*.

Table 5: The number of predated eider nests found in disturbed and undisturbed areas on Dyrhólaey Nature Reserve in 2012.

Area	**Number of predated nests**
Disturbed	6
Undisturbed	1

4.6: Historical data

The number of nests as given by the number of nests from which down was taken has remained fairly constant since data collection was started in 1992 with the majority of values being between 200 and 300 (see Figure 18). The highest value recorded was 428 nests in 1992, the lowest 150 in 2011.

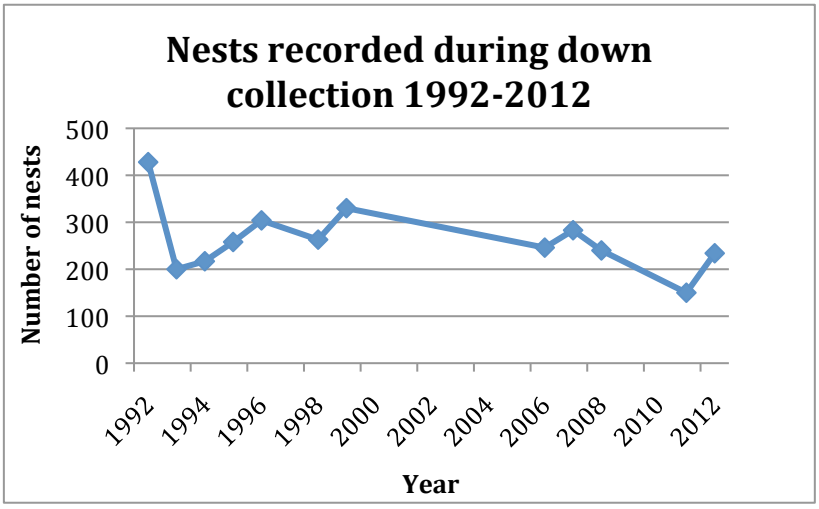

Figure 18: The number of nests recorded during down collection in years between 1992 and 2012 on Dyrhólaey Nature Reserve, Iceland.

It should be noted that this data represents the number of nests from which down was collected, not the total on the reserve, and may also reflect the amount of effort expended by the down harvesters in both locating the nests and collecting the down.

The number of nests can also be estimated from the weight of the down collected. This data was far more variable and, for some years, varied widely from the number of nests recorded by the down harvesters with values over 1000 nests (see Figure 19). There are many variables involved in this type of calculation, including factors such as the method of down collection, and it is unlikely to be very reliable.

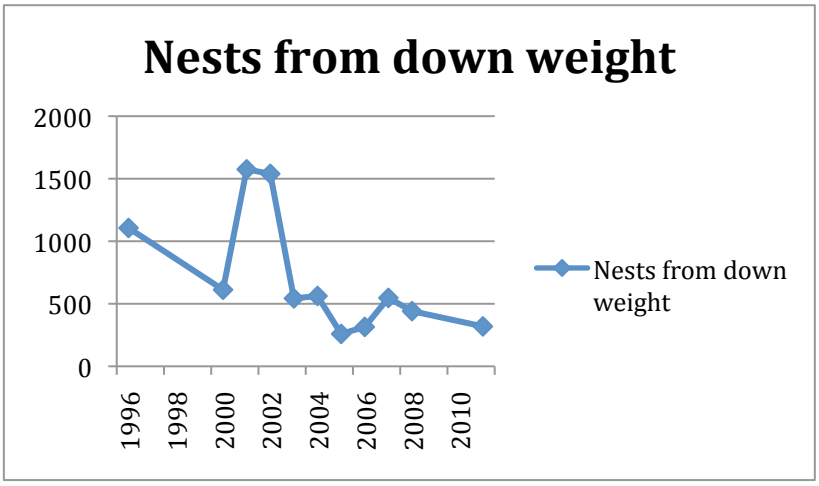

Figure 19: The number of eider nests calculated from the weight of eider down collected in years between 1996 and 2011 on Dyrhólaey Nature Reserve, Iceland.

The percentage of eider nests found in disturbed and that found in undisturbed areas has varied over time during the period for which there is data. In only three years out of twelve was there a higher percentage of nests in the disturbed areas. The current trend appears to indicate an increase in the number of birds using the undisturbed areas but more years of data will be required to confirm this. The percentage of nests found in undisturbed areas compared to disturbed areas in 2012 was higher than the average from 1992-2011 and is also the highest since data collection began in 1992.

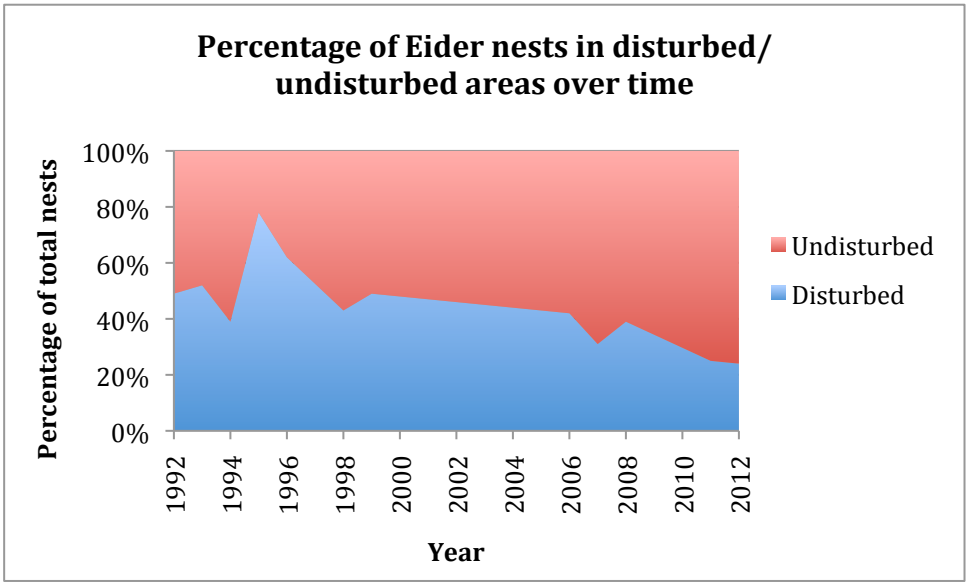

Figure 19: The percentage of eider nests located in disturbed and undisturbed areas from 1992 to 2012 on Dyrhólaey Nature Reserve, Iceland.

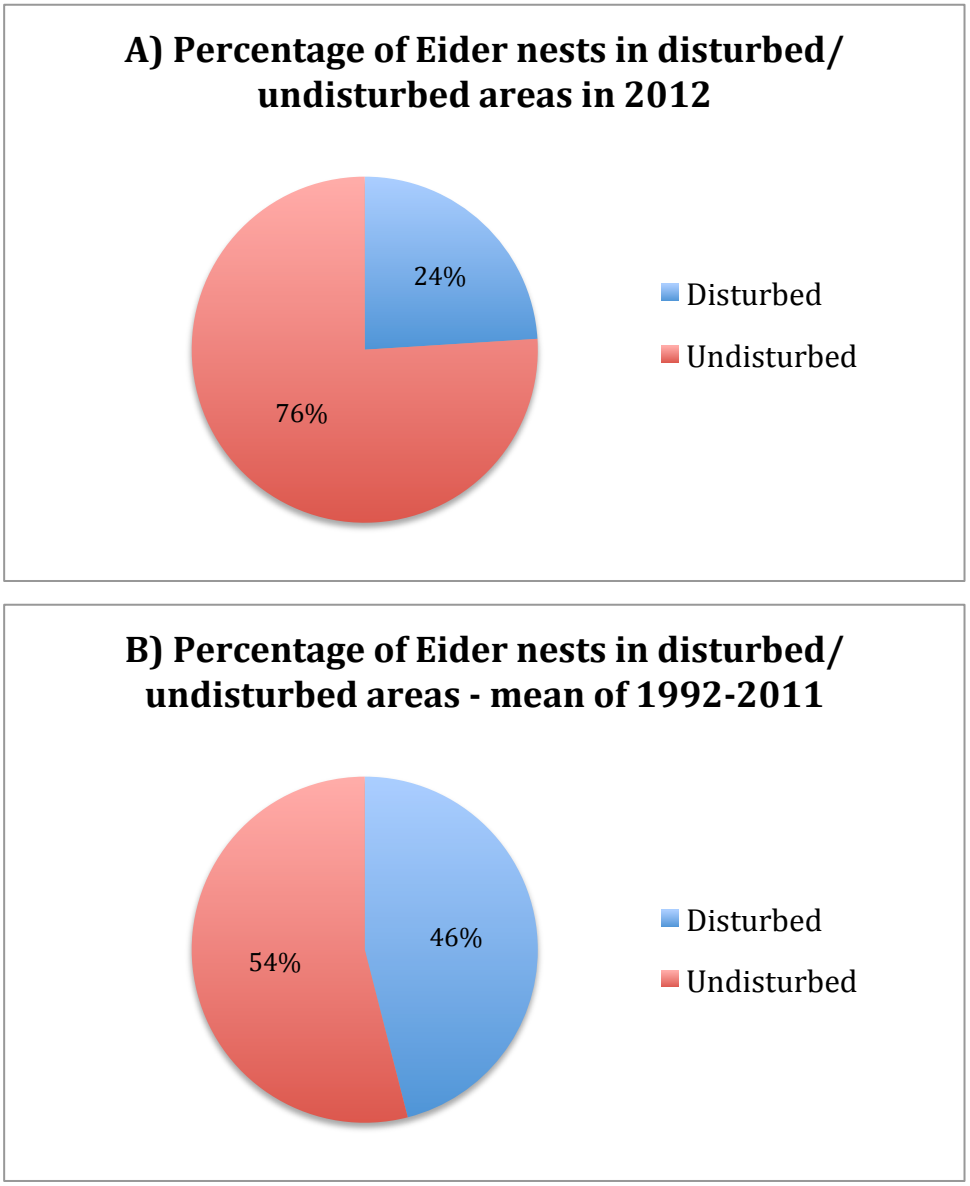

Figure 20: a) The percentages of eider nests in disturbed and undisturbed areas on Dyrhólaey Nature Reserve, Iceland in 2012. b) the mean percentages of eider nests in disturbed and undisturbed areas in the years for which there is data between 1992 and 2011.

5: Discussion

5.1: Distribution of nests

The distribution of nests across an area, although likely to reflect historic nest sites to an extent, can give indications of birds' reactions to factors affecting their environment, such as disturbance. This section will discuss the information that can be drawn from the distribution of eider nests on Dyrhólaey and assess the likelihood of contact between the incubating eiders and visitors to the reserve. The data provided by the down harvesters on nest locations and numbers over time will also be discussed here.

Eiders were found to nest in areas containing visitor access routes, both pedestrian and vehicular, so contact between humans and eiders on Dyrhólaey clearly occurs. Some nests were located close to a footpath and were clearly visible to visitors, so it follows that visitors were clearly visible to the nesting eiders. The vast majority of nests, however, were more than 50m away from access routes. Many nests were well hidden in uneven ground, vegetation, or around the north shore where the topography of the landscape hid them from view. This indicates that although eiders did nest within disturbed areas most birds avoided areas heavily used by humans in preference of quieter areas.

There is a clear concentration of nests along the northern shoreline where disturbance is at its lowest. Data collected by the down harvesters suggests that the proportion of the population nesting in this area has increased over time. This could reflect an increase in human disturbance on the parts of the reserve containing access routes; other studies have clearly demonstrated avoidance behaviour of breeding birds to access routes. Summers (2007), for example, studied capercailles in Scotland and found that the nesting birds avoided the access routes (in this case routes for vehicles, cyclists and pedestrians) and that avoidance increased with increasing use of the route. From the data collected by the down harvesters it is clear that the birds do alter their nest locations over time which suggests

that they may be able to adapt to constant regulated access management on the reserve by simply utilising the less disturbed areas. This of course assumes that some areas are left undisturbed and that there is sufficient nesting space available in these areas. It is possible that the less disturbed areas, particularly the busy north shore, have already reached their carrying capacity for breeding eiders.

The precise carrying capacity of the reserve is unknown as there are many other factors which may be affecting both population numbers, such as climate changes and food availability, and nest location selection, such as habitat or access to natural resources. There are areas in Lágey which have only a few eider nests at present but which are largely undisturbed and so may represent a currently untapped resource. One such area is that to the north west of Lágey, in the past there was a path around the coast here and it is possible that the closure of this may allow eiders to increase their colonisation of this area. Other than the existence of a path in this area in the past the reasons for the lack of eiders nesting here are unknown. There were a few nests found in the area so clearly it is suitable and similar habitats are utilised by eiders on other parts of the reserve; the routes taken by females and ducklings to the shore are unknown so it may be that access to the shore is more limited here, it is also further from the fresh water source on Lágey. Eiders on Dyrhólaey nest in a wide variety of habitats covering most of Lágey and the shore and can nest in close proximity to each other. This study did not further investigate nesting habitat suitability on the reserve however so the potential for migration within the reserve is unknown.

The level of activity on the reserve around the time of year that the birds are prospecting for nests is unknown but this factor may have had an impact on the birds' nest site choices. They are sensitive to disturbance when prospecting and are more easily flushed than during incubation when they have a significant investment in a site, so reducing disturbance at this time is important (Bolduc & Guillemette, 2003). However, if management seeks to encourage eiders to utilise less disturbed areas then access routes should remain constant throughout the breeding season with roads/paths that are open/closed during incubation having the same status during prospecting.

It is also worth noting that there was a concentration of nests around the reserve's one fresh water source and therefore the Háey road. Opening this road during prospecting/incubation could deter birds from using this area to nest and/or using the fresh water source, which is important for both adults during incubation and the newly hatched ducklings. Evidence suggests that fresh water is vital for the growth and survival of newly hatched ducklings so a nearby source is likely to be of great importance to breeding eiders. DeVink, Gilchrist, & Diamond (2005) found that altering salinity levels of water available to eider ducklings had a significant impact on survival with high salinity resulting in 100% mortality rates. This water source was the main natural resource identified during the study; the only other probable resource found was the brackish lake (and therefore access to it) which is likely to be an important source of water and food for eider ducklings. This study did not investigate the impacts of disturbance on eider ducklings after they leave the nest but this should be considered when making management decisions as ducklings are vulnerable to predation, particularly on land as they make their way to the rearing grounds (Keller, 1991).

The historical data on population gives no clear trend and the number of nests in 2012 is similar to that in past years indicating that the reserve can still support a stable population of eiders. The change in distribution may indicate that disturbance is having an increasing impact on the eiders, if only in terms of distribution, but there is not sufficient data to come to any definite conclusion. The apparent ability of the eiders to adapt to disturbance is useful as it implies that visitors and eiders can share the reserve. Care should be taken, however, as population level impacts may not be visible for many years in such a long lived bird. Productivity studies would give a more immediate indication of impact levels and it is unfortunate that there is no baseline data available but data from other colonies nearby may be found to be comparable.

5.2: Visitor behaviour

The previous section discusses the proximity of eider nests to access routes but this assumes that visitors remain on the access routes. Deviations from paths can greatly increase disturbance impacts particularly on species, like eiders, that can become

accustomed to routine disturbance. Birds next to paths may become accustomed to walkers but birds that are unaccustomed to disturbance are more likely to react badly if approached by a visitor who has strayed from the path (Nisbet, 2000).

On Dyrhólaey visitor behaviour was found to be generally good with only minor deviations. However evidence from both the observations carried out and anecdotal evidence suggests that there are particular areas which are at risk; for example the end of the closed road appears to be a tempting place to park. Visible animals also tempt visitors to leave the paths, which could be a concern for nesting eiders.

Decreasing the number of users which deviate from the marked access routes has been shown to be advantageous to breeding birds. Finney, Pearce-Higgins, Yalden, & Langston (2004) showed that when the percentage of users remaining on the paths was increased from less than 70% to 96% the avoidance distance of breeding Golden Plovers (the area around the paths which was avoided by the birds when selecting nesting sites) was decreased from 200 meters to 50 meters. This considerably increased the suitable nesting habitat available and therefore the carrying capacity of the site for this species. The importance of ensuring that visitors remain on the access routes is widely acknowledged; for example in a report by the American Society of Travel Agents one of the "10 commandments of eco-tourism" is as follows: "Always follow designated trails. Do not disturb animals, plants, or their natural habitats".

Since all but one of the nesting eiders in 2012 was more than 5.2m (the maximum AD measured) away from an open access route it is unlikely that visitors who remain on the paths would have a significant impact on an eider. If, however, visitors leave the path there is a strong potential for them to exceed this threshold and elicit a response from the birds. This report therefore advises that measures be put in place to reduce visitor deviations. Recommendations regarding methods that could decrease deviations from marked paths are given in the following section of this report.

5.3: Alert distances and assessment of disturbance impacts

This section will discuss the implications of the alert distances measured drawing conclusions from this data regarding the management of the reserve and the creation of buffer zones. An assessment will be made of the likely impacts of disturbance under the current visitor management regime. The limitations of this study and other factors which should be considered will also be discussed.

There was clear variation in incubating eiders' responses to disturbance with a large proportion of birds not showing any response. The impact that disturbance has on a bird is therefore specific to that individual and care should be taken if making generalisations to the whole population on Dyrhólaey. The ADs/FIDs measured were comparatively low; ADs found in other species using the same method have been many times higher, for example 60-400m in Mallards, 15-450m in Dunlin and up to 1000m in Brent Geese (Laurensen *et al.* 2005)(Bregnballe, Aaen, & Fox, 2009). This could be a reflection on the breeding stage at which the experiment was conducted since by late incubation the birds have a significant investment in their nest/eggs. It may also be due to eiders' ability to accustom themselves to the presence of humans, the frequency of visitors to the reserve, and the collection of down from eider nests each year (Nisbet, 2000). In terms of management this means that visitor use and the conservation aims of the reserve are likely to be compatible. If buffer zones were to be established the low ADs mean that these zones would not have to be very extensive to protect the breeding eiders.

The number of incubating eiders which responded to disturbance was much greater in the areas characterised as undisturbed. Again this could be due to the eiders' ability to become accustomed to disturbance. The implications of this for management are that visitor access to these areas should be more restricted as it has a higher potential to cause disturbance than in the currently used (disturbed) areas. Combined with the data regarding the distribution of nests on Dyrhólaey this means that the nesting areas along the north shore are likely to be most vulnerable to disturbance and so a larger buffer zone will be required to protect them.

As stated in the previous section only one nest on Dyrhólaey in 2012 was within the maximum alert distance. This indicates that behavioural responses to disturbance are unlikely to occur provided that access routes are adhered to. Based on the strong impacts of disturbance found in their study on nesting eiders Bolduc & Guillemette (2003) recommend that recreationists should avoid visiting eider colonies; however their studies were conducted in high density entirely undisturbed colonies. In the case of Dyrhólaey this study indicates that, at current visitor levels and during late incubation, unless the nests are very close to an access route or visitors leave the marked paths there is unlikely to be a significant effect of disturbance on incubating birds.

One factor that should be taken into account when using the data provided during this study is that it was only possible to carry out the disturbance experiment during late incubation. Other studies on eiders have shown that the timing of disturbance can have an effect on the magnitude of the impact. Bolduc & Guillemette (2003) investigated how varying the frequency and timing of disturbance altered the impact on breeding eider populations. Results showed that there was little alteration in impact due to increased frequency of visits to the colonies. However the timing of the visit was shown to have a strong effect on the impact level. Visits conducted later in the season were significantly less damaging to the eiders with far fewer nests abandoned/predated. Bolduc & Guillemette (2003) therefore recommend that any visits to eider colonies should be carried out as late in the season as possible. It is worth noting that these studies were carried out on uninhabited islands where the birds were highly unaccustomed to any form of human disturbance. A report compiled by Environment Canada also states that eiders are most vulnerable to disturbance-mediated impacts during early incubation and after hatching (Bérdard *et al.* 2008). For these reasons this study can only be used to indicate the level of impact likely on incubating eiders during late incubation; the impact may be much higher either earlier or later in the season and management should take this into consideration.

Another limitation is that it was only possible to test incubating birds' responses to a single human. In reality there are groups of many sizes visiting Dyrhólaey and larger groups or different behaviour may be considered more of a threat by an eider. This has implications for the creation of buffer zones in that they may need to be larger than the alert distances found in this study imply to account for the uncertainty described above.

Another factor which should be considered when making management decisions is that visitor numbers to Dyrhólaey may increase. The same access routes would be used and it is possible that an increase in visitors would therefore not decrease the carrying capacity of the reserve. It has been shown, however, that the impact of disturbance on some species increases with increasing frequency of disturbance or with larger numbers of people (Summers, McFarlane, & Pearce-Higgins, 2007)(Velando & Munilla, 2011). Although one study showed that increased frequency of visits to an eider colony had little impact on productivity it is possible that increasing use of the reserve could result in a greater impact on the breeding eider population (Bolduc & Guillemette, 2003). The population, and preferably productivity, of eiders on the reserve should therefore be monitored each year and management adapted accordingly.

5.4: Disturbance and predation

The high number of birds showing a flushing response to human disturbance is of concern due to the increase in risk of predation that this causes. Normally if an incubating bird leaves the nest she will cover the eggs in down to avoid predation, but if flushed this action is not taken leaving eggs vulnerable. Bolduc & Guillemette (2003) found that disturbance combined with the presence of predators (in this case Gulls) was highly detrimental to incubating eider populations. A study on eiders nesting on Spitsbergen found that 73% of eggs were predated, the main predators being gulls (Ahlén & Andersson, 1970). Studies have also shown that human presence on a site can increase the abundance of predators. Watson & Moss (2004) studied breeding Ptarmigans near a ski development in Scotland and found that the increased human presence resulted in an increase in the populations of generalist predators such as Carrion Crows. This was correlated with a decrease in Ptarmigan productivity within a four mile radius of the site.

Dyrhólaey is fortunate in this respect as there are a limited number of resident predators. There are a few pairs of gulls breeding in the vicinity but no large colonies like those that have been found to devastate eider colonies in other areas (e.g. Ahlén & Andersson, 1970).

The other potential predators in the area include arctic skuas, occational visiting great skuas and occational arctic foxes. The latter have been lethally controlled on Dyrholaey in the recent past and there are none breeding on the reserve. The number of nests found to have been predated in 2012 was low which concurs with Donehower & Bird's (2008) study and is therefore likely to support the theory that predation is much stronger post-hatching. Donehower & Bird (2008) found that, although much of the predation during incubation was mediated by human disturbance, egg predation was very low. They then monitored duckling predation after leaving the nest and found that this was extremely high.

The predation rates on eider nests in 2012 on Dyrholaey were low. Egg predation was found to be higher in disturbed areas compared with undisturbed areas but there was no evidence of predation in nests close to access routes suggests that proximity to humans is not always detrimental. The most likely predator that is resident on the reserve is a pair of arctic skuas, which nest near the main concentration of eider nests on Laey. No attempts on eiders by the skuas were seen but they were observed being mobbed by arctic terns on many occasions.

This study, due to time restrictions, did not investigate the effects of disturbance on eider ducklings after leaving the nest. Various studies have shown that young eider ducklings are highly vulnerable to predation and that disturbance can exacerbate this effect (see section on predation for further details). Keller (1991) found that disturbance resulted in an increased risk of predation to ducklings both onshore and in the water and that the impact of disturbance was greater onshore. They found that disturbance could alter the behaviour of a crèche for as much as 35 minutes afterwards. Ahlén & Andersson's (1970) study also showed a much stronger impact of predation on ducklings on land compared to on the water. These studies indicate that the eider ducklings will be most vulnerable during their journey from the nest to the nearest suitable foraging area. Since disturbance during this time could have a significant detrimental effect on duckling survival this should also be taken into account when making management decisions and may require further study.

5.5: Recommendations

The main conclusion of this paper is that the current management of visitors to the reserve during the eider incubation period is likely to be satisfactory for the purpose of eider conservation and should be continued. Monitoring programs should be set up to ensure that management is successful and further research may be required to assess factors not covered by this study, particularly the likely impact of disturbance at different times during the breeding season. When implementing the recommendations given in this study it should always be remembered that the results from this study apply only to the mid or late incubation period. Another consideration is that this kind of data only indicates likely impacts, it cannot be used to measure population level impacts. These assessments and recommendations are based on the aims of management being to maintain the current eider population levels and, if compatible, to continue to allow human use of the reserve. The following paragraph gives a summary of the impact assessment.

The avoidance of access routes shown by the distribution of nests in 2012 and changes in distribution in the past may indicate that use of access routes results in areas of the reserve being unusable by eiders thus potentially decreasing the carrying capacity. However distribution changes and a fairly stable population indicate that eiders may be able to adapt to a level of disturbance by altering their nest sites provided that enough suitable nesting area is left undisturbed. Further study will be required to confirm this adaptation ability and it should not be relied upon. The alert distance displayed by incubating eiders on Dyrhólaey is relatively small meaning that large buffer zones may not be required, at least during incubation, and that most of the nest sites in 2012 were unlikely to be significantly impacted by visitors using the open access routes. Alert distances were much larger in less disturbed areas indicating an increased sensitivity to disturbance and the need for larger buffer zones. Predation was also low in 2012 with only a few predators being seen regularly on the reserve.

The breeding population on Dyrhólaey should be monitored and if the population decreases additional protection may be required. Productivity should also be monitored as this will reveal issues much faster than changes in population. Alterations in the

distribution of nests may not be an issue as this appears to happen naturally and may help the eiders to adapt to the presence of visitors on the reserve but this cannot be assumed. Key resources, for example the fresh water pond, should, however, remain available, and buffer zones should be maintained around both these and areas with a high concentration of nesting eiders. The northern shoreline and other relatively undisturbed areas require the most protection as disturbance appears to have a stronger impact on birds from these areas. Deviations from the marked access routes should be minimised as this could significantly increase disturbance impacts.

The following section gives management actions that may improve the management of the reserve for the conservation of the eiders that breed there.

5.5.1: Management actions:

1) Establish buffer zones around important nesting areas and natural resources

   The fresh water source on Lágey and the areas with a high concentration of nesting eiders should be protected from disturbance during incubation and preferably during prospecting as well. Buffer zone size can be calculated using the maximum AD plus an additional distance to ensure prevention of disturbance. An example of this additional distance as recommended by Bentrup (2008) is 130-170 feet (40-50m). The nesting areas on the northern shoreline may require a larger buffer zone due to their increased sensitivity to disturbance and the use of these areas during the chick rearing period. This study recommends that access to these areas, and to the top of the small cliffs behind the nesting areas where observers are visible to the eiders below, should be restricted. Maintaining the same access management throughout the season and between years will also allow the eider population to adapt to regular use of Dyrhólaey by visitors.

2) Continue to close the Háey road during breeding season.

   This is important in order to ensure that the reserve's one fresh water source, which is important for newly fledged eider chicks, is left undisturbed and available. Other

species of birds also use this water source on a regular basis and a further impact assessment may be required to establish whether allowing access to Háey after the eider breeding season is detrimental to other breeding bird species (Pers. Comm.). Closure of this access route also greatly increases the undisturbed area available to all bird species for breeding which increases the carrying capacity for these species on the reserve. Closure of this road will assist in the creation of buffer zones as described above.

3) Ensure that visitors remain on the marked access routes.

   As stated previously there is a wealth of scientific evidence to suggest that deviations from access routes can significantly increase the impact of visitor access on breeding bird populations. Reduction of this issue could be achieved in various ways including warden's presence, increasing the clarity of paths and further interpretation. A report compiled by Scottish Natural Heritage suggests the creation of "viewing facilities" where visitors can view the wildlife from a safe distance which will help prevent individuals searching for the wildlife and causing greater disturbance. If there is a nest close to the path, which will therefore be highly visible to tourists, the creation of a viewpoint on the path with interpretation explaining the importance of not disturbing the incubating bird could prevent visitors from leaving the path to get a closer look. Increasing the clarity of footpaths can also decrease disturbance; Finney *et al.* (2004) found that increasing path clarity increased the number of visitors remaining on the paths from <70% to 96% and increased the number of golden plovers nesting within 200m of the path by 50%.

4) Increase interpretation and awareness raising efforts on the reserve.

   This can help to encourage ethical behaviour on reserves, which is recommended to reduce the disturbance caused by visitors (DeLong, 2002). A greater understanding of the reserve's wildlife and the threats posed by visitors should decrease the likelihood of damaging practices occurring. Increasing the information available to visitors is also likely to enhance visitor enjoyment and understanding. This can be undertaken both

directly with the visitors themselves and with tour operators/guides and can be done in person, with leaflets and with interpretative panels on the reserve.

5) Continue employment of a reserve warden.

   The presence of a warden on the reserve will contribute to monitoring, ensure compliance with reserve rules, and contribute to awareness-raising efforts. The benefits of these are described above and in the following section.

6) Continue consultation and community involvement efforts.

   This should be done to ensure good communication is maintained between different interest groups and a good understanding of the conservation and management of the reserve is maintained. The importance of involving stakeholders in the management of reserve is widely accepted; for example in a report by the House of Commons Committee (1995a) it is stated that managers should use consultation to find solutions to management issues. This could also have benefits to the reserve in terms of data collection which could be carried out by the down harvesters or local interest groups.

7) Continue to design and implement a long-term management plan

   Not only will this assist the tourism industry but it may also be of benefit to the nesting eiders as they may be able to adapt to a particular management regime. This adaptation could be in the form of becoming more accustomed to human presence in certain areas or of moving nest sites to less disturbed areas. Either of these adaptations, if they occur, are likely to be beneficial. Increasing the predictability of visitor use of a reserve is recommended to reduce the impacts of disturbance by habituation and retaining the same access management over many years will help to achieve this (DeLong, 2002).

8) Design and implement a monitoring program

The need for monitoring and research to improve eider conservation is highlighted by CAFF (Circumpolar Seabird Working Group, 1997). In the past there has been little formal monitoring undertaken on Dyrhólaey resulting in a lack of baseline data. A monitoring programme should be set up to ensure that baseline data is available on which to base and test management decisions. Monitoring is a useful indicator of the effectiveness of management practices (Sidaway, 1994).

Monitoring of eiders on Dyrholaey should, ideally, include the following:

- Whole reserve population/nest counts
- Nest locations
- Productivity (either simply expressed as the proportion of nests that successfully hatched chicks or as the number of hatched eggs per nest). In the short term this could also be used to compare this colony with others along the south coast of Iceland.
- Predation levels using the method given in this report, which could be combined with productivity monitoring.
- The date of first prospecting female, incubating female, egg seen and chick hatched, and the last nest to hatch chicks.

There are various mechanisms for achieving this, the most obvious being including such tasks in the remit of the reserve warden. Collaborating with the down harvesters would also be an effective way to gain data. The down harvesters already collect various types of data on the eiders each year, and they are very familiar with the nest locations. This would also be advantageous as, because the harvesters will be visiting the colonies in any case, it would reduce the number of visits to the colonies. Other mechanisms include hiring researchers or asking for volunteers, either local or students/young professionals.

10) Further study

Due to the limitations of the current study various factors have not been taken into account which may be of importance for the management of Dyrhólaey. The following

are recommendations as to future studies that could be undertaken to further inform management decisions.

- Assessment of the impact of visitor access on the ducklings after they leave the nest. In particular the routes that the birds use to travel to the chick rearing areas should be mapped and, if possible, kept clear. The young ducklings are very vulnerable to predation and disturbance at this stage could severely reduce their chances of survival. Establishing routes free from disturbance could mitigate this.
- Assessment of the impact of visitor access on the prospecting eiders/female eiders during early incubation when they are likely to be more sensitive to disturbance than at the late incubation stage tested by this study.

11) Continue to allow down collection provided that current good practice is continued

Down collection is a traditional practice both on Dyrhólaey and across Iceland and can be an important income supplement in isolated communities. It is a non-consumptive industry that, when done with care, causes little or no harm to the eiders. Conservation of Arctic Flora and Fauna (CAFF) state that they encourage non-consumptive use of eiders for the above reasons (Circumpolar Seabird Working Group, 1997). This report recommends that down collection on the reserve continues and that the down harvesters continue to follow the good practice methods currently in place. This traditional industry could also be included in reserve interpretation as it has made great contributions to eider conservation over time both from the symbiotic relationship between individual collectors and the birds that they protect and the protective legislation that the industry resulted in.

The literature review carried out as part of this study indicates that the following good practices should be observed:

- Limit visits to the colony as much as possible, especially in the more vulnerable prospecting/early incubation and hatching stages. This is particularly important for the colony on the North shore as they are more susceptible to disturbance.

- Leave a sufficient amount of the down in the nest to allow the bird to cover the eggs when she leaves the nest. Although straw has been shown to provide sufficient insulation for the eggs there is no data available on how this practice affects the female eider's predation-prevention techniques.

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